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Method and Apparatus for Examining Vessels

The invention relates to a method for examining vessels, in particular of the retina, in accordance with the features cited in the preamble to patent claim 1. The invention furthermore relates to an apparatus for performing the method.

5   Known from EP 0 631 757 B1 are such a method and such an apparatus, which are embodied for measuring the flow velocity of a liquid, in particular blood. The frequency shift of a laser beam reflected in the liquid is determined in accordance with the optical Doppler effect, whereby two-dimensional grid-field scanning is performed by means of the laser beam. The Doppler shift is calculated from the

10   temporal variation in the measured intensity of the reflected light and the flow velocity is determined therefrom.

Retinal vessels are the mirror of the vascular system. Arteriosclerotic vessel changes in the brain are associated with changes in ocular fundus vessels. Generalized and focal constrictions in retinal vessels, signs of arteriovenous

15   crossing, and retinal microinfarcts have a strong correlation to hypertension and stroke. In one epidemiological study (Beaver Dam Eye Study), it could be demonstrated that the prevalence of retinal emboli was 0.3% between the ages of 43 and 54, 1.2% between the ages of 55 and 64, 1.3% between the ages of 65 and 74, and 3.1% is people older than 75 years of age. After adjusting the control

20   group for age, sex, and systemic factors, people with retinal emboli have a 2.6-times greater risk of dying as a result of stroke. The authors concluded that discovery of retinal emboli in a non-symptomatic patient with introduction of early therapy in terms of the underlying basic illness is advantageous for the patient's prognosis.

In one study with 11,000 subjects, the ocular fundus was examined with respect to retinal vascular abnormalities and a possible connection to arterial blood pressure. The authors were able to demonstrate by means of conventional ophthalmological examination methods that for every 10-mmHg increase in mean arterial pressure,

5   first, the ratio of arterial and venous diameter decreased by 0.2 units, and, second, focal arterial constrictions increased with an odds ratio of 2. Furthermore, a linear correlation between blood pressure and the retinal vessel risk index was identified. The image data processed were evaluated by purely manual measurements.

Stroke, one of the most severe consequences of arterial hypertension, is avoidable.

10   International studies clearly demonstrate that up to a 70% reduction in stroke can be achieved by purposefully and resolutely reducing risk factors for stroke, especially high blood pressure. Of decisive importance for successfully preventing terminal organ damage due to arterial hypertension within the overall population is identifying and treating endangered patients with high vascular risk.

15   Investigating a retinal vessel risk index that indicates vascular damage to the cerebrovascular system could be employed for targeted screening for a risk of stroke in large segments of the population. In many vascular illnesses, the cause of the lack of oxygen is thickening of the vascular wall. It is known that the thickness of the internal carotid artery intima-media represents a very important

20   risk factor when evaluating the risk of arteriosclerosis.

Starting from this point, the object of the invention is to further develop the method and the apparatus of the aforesaid type such that further examinations of retinal vessels can be performed with low complexity. The examinations should yield precise measurement results that in particular provide important information

25   about any diseases the person being examined has and/or about the health of the

person being examined. In addition, novel fields of application and employment shall open up for the method and the apparatus, which is also called an ophthalmoscope.

This object with respect to the method is achieved in accordance with the features cited in patent claim 1. With regard to the method [sic], the object is achieved in accordance with the features cited in patent claim 5.

The inventively suggested method and the apparatus suggested for the performance thereof enable the vascular wall thickness of retinal vessels to be determined without particular complexity. This creates substantially broadened employment options for scanning laser devices and/or ophthalmoscopes. In particular, the examinations cited in the foregoing can be performed with great precision so that necessary therapies can be introduced based on risks established in this manner. The inventive non-invasive determination of the vascular wall thickness of retinal vessels enables screening of broad segments of the population with minimum complexity, whereby early detection of any disease can substantially improve the quality of life of the patient in question and in addition substantial reductions in costs can be obtained in terms of health care.

The scanning laser Doppler flowmetry measurement method enables simultaneous representation of retinal vessels by means of reflectivity and by means of the laser Doppler shift. The reflectivity images yield the external diameter of the retinal vessels, the Doppler images yield the diameter of the blood column moved. The vascular wall thickness of retinal vessels is determined from the difference of the two images. The vascular wall thickness can be determined by comparing the moved blood column (laser Doppler image) to the entire vessel (reflectivity

images). Since the retina represents a visible portion of the brain, vascular risk in

terms of oxygen supply to the brain can be assessed by observing retinal vessels.

One very important parameter is vascular wall thickness. In accordance with the

invention, non-invasive determination of vascular wall thickness of retinal vessels

5   occurs by means of scanning laser Doppler.

Further developments and special embodiments of the invention are provided in

the subordinate claims and in the following specification.

The invention is explained in greater detail using the drawings without this

imposing any restriction.

10   Fig. 1   is a diagram with data for a retinal vessel that have been determined from

                 a reflectivity image;

         Fig. 2   is the reflectivity image upon which Fig. 1 is based;

         Fig. 3   is a diagram of the data for a retinal vessel that have been determined from

                 a laser Doppler image;

15   Fig. 4   is the laser Doppler image upon which Fig. 3 is based.

Fig. 1 is a typical diagram, corresponding to a retinal vessel, the reflectivity image

of which is shown in Fig. 2. The exterior diameter of the vessel is marked with

the arrow 2. At least an approximation of the distance between the two maximum

values is acquired between which are the minimum values corresponding to the

20   vessel walls. The abscissa is divided into micrometers and thus the external

diameter of the vessel is 190 μm.

The diagram in Fig. 2 illustrates a typical course corresponding to a moved blood

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column after evaluation of the laser Doppler image shown in Fig. 3. Such a laser

Doppler image can be produced for instance by the method for measuring flow

velocity of the blood or the device embodied appropriately, described in the cited

EP 0 631 757. The inventor recognized that the interior diameter of the vessel can

5   be deduced by imaging and determining the moved blood column. Until today

from a practical aspect and in particular given achievable measurement precision

it has not been possible to measure the vessel interior directly. On the contrary, in

accordance with the invention the interior diameter is measured indirectly by

determining the moved blood column. Taking into account the abscissa scale of

10   diagram 2, given in μm, in accordance with arrow 4 the vessel has an interior

diameter of 90 μm.

The vessel wall thickness is determined from values obtained in this manner for

the exterior diameter and the interior diameter of the vessel in a preferred manner

and with little complexity, in particular in terms of computer performance, by

15   finding the difference or correlating these data.

In the apparatus for performing the method, the evaluation unit provided in a laser

device for examining the ocular fundus or image evaluation is employed, whereby

in addition the computer of the apparatus is embodied such that finding the

difference or correlating the data determined is performed inventively.